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Renewable energy readiness assessment for North African countries

Diala Hawila [a], Md. Alam Hossain Mondal [a,b,*], Scott Kennedy [a], Toufic Mezher [a]

[a] Masdar Institute of Science and Technology, Institute Center for Smart and Sustainable Systems (iSmart), PO Box 54224, Abu Dhabi, United Arab Emirates
[b] Energy Institute, Bangladesh Atomic Energy Commission, Dhaka, Bangladesh

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ABSTRACT

Energy is an important input for national socio-economic development. The current trends of energy supply and demand are not sustainable because of the expected huge gap between demand and supply in the future. The fossil fuels resources are limited and use of these fuels has a negative impact in the environment. Holding energy at a secure level and global climate at a safe level require integration of renewable energy technologies (RETs) in the energy supply-mix. Development of RETs in a country depends on its renewable energy readiness (RE-Readiness) that indicates the gaps and strengths of their development. In light of the various initiatives proposed to turn North Africa into a renewable energy producer and extend its electricity supply to its neighboring European counties, it demands to assess the RE-Readiness. The main object of this paper is to develop and disseminate an assessment framework to find North African countries RE-Readiness for deployment of RETs. This framework is adopted in which the paper applies a consistent methodology across all the North African countries' to assess the present state of infrastructure, institutions and human capital factors to adopt and deploy RETs. Each of the factors is assigned a weight and a score between 1 and 7, with 1 being the lowest and 7 the highest score. From this developed assessment framework, it is found Morocco received the highest RE-Readiness score means that the country is more ready to invest in RETs than the other countries in North Africa. This assessment identifies the gaps and strengths for the deployment of RETs in these countries and serves as a first step towards proposing renewable energy diffusion strategies that will contribute to their environmental, social and economic development.

Contents

* Corresponding author at: Energy Institute, Bangladesh Atomic Energy Commission, Dhaka, Bangladesh. Tel.: +0088027790009.
E-mail address: amondal@uni-bonn.de (Md.A.H. Mondal).

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1. Introduction

The North African countries are mostly endowed with rich hydrocarbon resources at the exception of Morocco and Tunisia. Renewable energy adoption is driven by environmental concerns, enhanced energy security, and European proposition to install large-scale solar power plants and wind parks and establish an intercontinental power grid in order to transport the electricity to Europe. The Desertec Industrial Initiative (DII), constituted by German companies in October 2009, proposes an investment of €400 billion into the construction of future North African solar power plants and their connection to the European grid through submarine cables. The Mediterranean Solar Plan (MSP) aims to develop additional 20 GW by 2020 along with the necessary electricity transmission capacity, including international interconnections. These initiatives have been endorsed by the European countries through the formation of the Union for the Mediterranean, a political instrument of dialog and cooperation between the European Union (EU) and states of the southern and eastern Mediterranean. These initiatives seem to be feasible and promising according to the generalist technical economic studies that principally represent the European outlook on these projects. These initiatives proposed to turn North Africa into a renewable energy producer and extend its electricity supply to its neighboring European countries. However, the study on renewable energy readiness (RE-Readiness) assessment in these countries is lacking. This paper indicates the critical success factors that are important for the deployment of RETs and assesses RE-Readiness to promote RETs in different North African states namely Algeria, Egypt, Libya, Morocco, and Tunisia. A map to improve geographical understanding of North African countries is shown in Fig. 1 [1].

1.1. Renewable energy readiness

International Renewable Energy Agency (IRENA) defines RE-Readiness as “when actors are able to deploy renewables where they are the best option, accounting for all economic, social and environmental criteria”. The readiness conducts its assessments by looking at “the current state of national readiness, across the project lifecycle, from national energy strategy and policy, to building, operation and maintenance, with capacity-building cutting across all these items” [2].

On a national level, RE-Readiness is an indication of the country's realization of the need for renewable energy and its ability to introduce and support renewable energy projects. In this report, RE-Readiness is defined as the level of development of a county's infrastructure, institutions and human capital factors that influence the attractiveness of investing in renewable energy projects and play a role in enhancing the reliability of RETs to ensure their sustainable deployment [3].

1.2. Methodology

The RE-Readiness for each country will be determined by evaluating their readiness to adopt RETs by assessing the enabling factors to deploy of RETs in terms of three pillars namely infrastructure, institution and human capital. Name of the factors and sub-factors of these pillars are given in Table 1. The Global Competitiveness Report (GCR) 2011–2012 developed by the World Economic Forum [4] was used to obtain scores for many factors and indices in this paper. The GCR measures countries competitiveness levels by assessing the competitiveness factors and giving them a score between 1 and 7. Similarly, the RE-Readiness Index is a score between 1 and 7, with 1 being the lowest and 7 the highest.

The scoring criteria for some factors and sub-factors can be initially assessed from a qualitative range of “poor” to “very good” and then translated into a score from 1 for “poor” to 4 for “very

Fig. 1. A map of North African countries.

Table 1
Name of factors and sub-factors related to RE-Readiness.

Infrastructure	(1) Assessment of natural resources • Renewable energy potential • Energy security (2) Country overall infrastructure (3) System requirements • Grid capacity and robustness (4) Market infrastructure • Goods market efficiency • Market deregulations • Renewable energy supply chain • Market distortions and competitiveness (5) Energy access • Expected energy demand growth • Electrification rate and quality of electricity supply
Institutions	(1) General institutions (2) Key policies • Institutional framework • Identified targets and policy mechanisms • Financial market development • Macroeconomic development
Human capital	(1) Technical and commercial skills • Higher education and training • Capacity building • Available renewable energy experts • Labor market efficiency (2) Technology adaptiveness and diffusion • Technological adoption readiness • Innovation and R&D (3) Awareness among consumers, investors and decision makers • Resources availability • Consumer and social acceptance

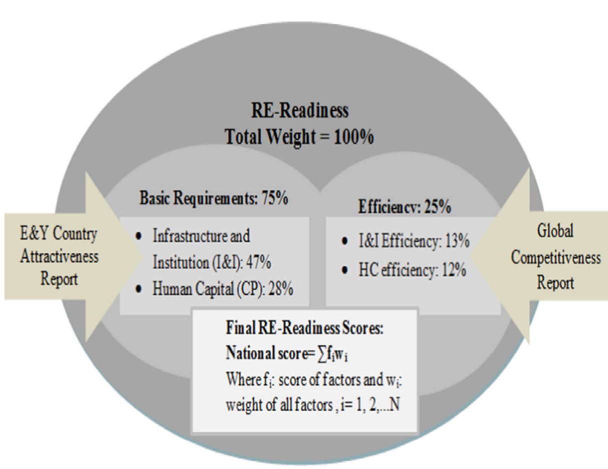

Fig. 2. Method to find the RE-Readiness final score.

good". These are then normalized into a score between 1 and 7. The scores are: 1 (poor), 2 (fair), 3 (good) and 4 (very good), corresponding to 1, 2.33, 4.66 and 7, respectively. For other factors and sub-factors that are related to quantitative data, this research applied different quantitative techniques to get an RE-Readiness score from 1 to 7.

This paper quantitatively (score between 1 and 7) assessed each of these factors and their respective sub-factors related to deployment of RETs and discussed in next sections. It determined the weights for all factors and sub-factors based on Global Competitiveness Report [4] and Ernst and Young Country Attractiveness Report [5]. It fixed the weights of different factors and sub-factors on the mentioned three main pillars (infrastructure, institutions and human capital) for the deployment of RETs (Fig. 2). The factors are divided into basic requirements to the deployment of RETs, and efficiency enhancers that would play a role in enhancing the diffusion of any technology on a national level. Then it used multi-criteria decision making (MCDM) technique to get the final RE-Readiness score for each selected countries. The technique provides solutions to the problems involving multiple conflicting objectives. MCDM is a general class of operations research model which deals with problems involving a number of decision criteria [6]. Then the study applied the Weighted Sum Method (WSM) [7] for final RE-Readiness assessment. Finally, the paper presents a summary RE-Readiness table and draws a comprehensive figure that compares the countries' level of readiness in terms of each factor and gives conclusions. The following sections discuss the pillars and given scores related to RE-Readiness.

2. Infrastructure

This section explores the country's physical capability to deploy renewable energy, in terms of availability of natural resources, the country's overall infrastructure, and the systems capability to support additional renewable energy capacity, and to export produced electricity to neighboring countries as planned. It also explores the market infrastructure to study the ease of technology deployment in the country and identify the market barriers. It looks at the energy access situation of the country to identify potential need for added capacity.

2.1. Assessment of natural resources

2.1.1. Renewable energy potential

The North African zone is endowed with widely diversified renewable energy resources: biogenic, hydrothermal, geothermal, marine, wind, and solar [8], enabling the region to produce power from these resources consistently. In terms of solar potential, North Africa is vastly covered by millions of km^2 that are suitable for concentrating solar thermal power (CSP) plants with respect to the low humidity and land slope of less than 5% and uncultivated land cover. The solar radiation conditions of North Africa permit CSP plants to generate 0.25 TWh/km^2 annually. Solar radiation data for each country is presented in Table 2. In the case where co-generation is applied, multi-effect distillation (MED) plants waste heat can be utilized for desalination with high efficiency to produce billions of cubic meters of fresh water [9]. The wind speeds for the five countries also given in Table 2. The best potential for wind energy is located in Egypt and Morocco. Hydropower potential is also substantial in the region, with the most significant technical potential available in Egypt (2.8 GW) and Morocco (2.5 GW). As for geothermal potential, considerable potential is available in Algeria and Libya. Some potentially exploitable sites have already been located in most of the countries. Finally, biomass potential is promising due to very high total waste resources. Their energy valorization potential has been estimated in Algeria, Egypt, Morocco, Tunisia indicating significant results, with 47 Mt per year

Table 2
Renewable energy potential.

Resource	Algeria [11–13]	Egypt [14–16]	Libya [17,18]	Morocco [10,19,20]	Tunisia [10,21,22]
Direct Solar Radiation (kWh/m^2/yr)	1700–2600	2000–3200	2590–2960	1800–2550	1500–1900
Wind (m/s)	Wind speeds > 4 and > 6 in Adrar	6–11	6–11	4.7–10.4	7–10
Hydro	Low potential	Big potential for large hydro but not adequate for small and medium projects	No discovered substantial potential	Technical potential of 2500 MW. Good potential for small and mini-hydro	Poor potential for large hydro. Three identified sites with good potential for small/medium projects
Geothermal	200 sources in the North-East and Nord-West. Confirmed capacity > 700 MW from Albian sources	Potential for development of geothermal resources along the Red Sea and Gulf of Suez coasts	No discovered substantial potential	Significant potential exists in the north-east	Limited to direct utilization, and not electricity generation
Biomass	3.7 million TOE coming from forests and 1.33 million of TOE per year coming from agricultural and urban wastes	16 million tons per year of agricultural residue and urban waste of 47 M tons per year	Biomass potential is estimated at 2 TWh/year. Unsuitable for large scale power generation	Urban domestic wastes estimated at 3 M tons per year	Organic wastes annually produced in Tunisia are estimated at more than 30 million tons

Table 3
North Africa hydrocarbon resources [23].

	Algeria	Egypt	Libya	Morocco	Tunisia
Oil proven reserves million bbl-(1 January 2011 est.)	12,200	4400	46,420	0.68	425
Oil production (million bbl/day-2010 est.)	2.078	0.6626	1.789	0.003938	0.08372
Oil exports (million bbl/day-2009 est.)	1.694	0.163	1.385	0.025	0.091
Oil imports bbl/day (2009 est.)	18,180	177,200	575	221,000	78,460
Natural gas proven reserves trillion m^3 (1 January 2011 est.)	4.502	2.186	1.548	0.0014	0.065
Natural gas production billion m^3 (2010 est.)	85.14	62.69	15.9	0.060	3.6
Natural gas exports billion m^3 (2010 est.)	55.28	18.32	9.89	0	0
Natural gas imports billion m^3 (2009 est.)	0	0	0	0.5	1.25

in Egypt and urban wastes estimated at 3 Mt per year in Morocco. In general, biomass data for the region are not always available [10].

It is clear that the North African region has abundant untapped energy resources. Egypt and Morocco score the highest of 7.0 due to their high potential in solar, wind, hydro, biomass and potentially geothermal resources. Algeria comes next because of its geothermal potential in addition to its substantial solar resources with a score of 6.5. Finally Tunisia and Libya score 6.0 due to their sole reliance on solar and biomass resources with little wind potential.

2.1.2. Energy security

As discussed in the above section, the North African region is rich in renewable energy resources that mainly remain untapped. One of the factors delaying the exploitation of these resources is the heavy endowment of the region with hydrocarbon resources, with the exception of Morocco and Tunisia as shown in Table 3.

Libya is the richest North African country in hydrocarbons and it has the world's 9th largest proven oil reserves and is also a main exporter of natural gas. Algeria is a major producer and exporter of oil and natural gas, mostly to Europe [13]. Egypt is the world's number 12 exporter of natural gas. These countries are currently self sufficient with energy, and their decision to adopt renewable energy is not driven by a present lack of energy security. However, Morocco and Tunisia will be more drawn to invest in RET projects to minimize spending and dependence on foreign energy sources. It should be noted that the Middle East and North Africa (MENA) region has essentially no coal reserves [24]. Therefore assessment is done on the basis of proven oil and gas reserves equally. Scores are assigned from 1 to 7 according to the availability of reserves, 1 given to countries blonging to the highest percentile of oil and gas reserves endowment and 7 being assigned to the lowest.

Table 4
Energy security scores.

Country	Oil rank	Score	Gas rank	Score	Average score
Algeria	16	1	10	1	1
Egypt	26	2	16	1	1.5
Libya	9	1	22	2	1.5
Morocco	98	7	97	6	6.5
Tunisia	53	4	59	4	4

When a country has rich oil and gas reserves it is less likely to invest in RETs. The RE-Readiness scores for the studied coutries are given in Table 4.

2.2. Country overall infrastructure

A country's general infrastructure affects its ability to implement large scale projects, specifically RETs that depend on logistical requirements. In order to import parts, transport them in remote areas, the country should be well equipped with a robust infrastructure, in terms of quality of roads, communications, and other logistics. A well-developed infrastructure minimizes the effect of distances between regions, integrating the national market and connecting it at low cost to markets in other countries and regions [23]. The Global Competitiveness Report 2011–2012 [3] gives scores for country overall infrastructure on a scale from 1 to 7, 1 being the lowest and 7 the highest. Tunisa scores the highest in overall infrastructure with 5.0 [4] (compared to 5.5 in 2010 [25]). The Tunisian government has invested heavily in the country's infrastructure since 1995. Twenty thousands kilometers of good-quality roads link all parts of the country, in addition to six commercial seaports and seven international airports. Morocco's infrastructure comes next with a score of 4.3 (up from 4.1 in 2010).

Progress has been made on improving the transportation and information and communication technology (ICT) infrastructure but Morocco's logistic performance indicators still slightly lag behind peer countries. Egypt's infrastructure is still being developed and scores 3.9 (compared to 4.3 in 2010) with projects taking place on a huge scale. Investments are set to increase by 75% by 2012–2013 to $36.6 billion for the establishment of 52 infrastructure projects including port development and road building. As for Algeria, its overall infrastructure scores 3.7; but the President's five-year plan (2009–2014) includes an increase from $120 billion to $150 billion in spending to improve national infrastructure [26]. Finally, Libya scored the least at 3.2 before the conflicts in 2011. Currently, it is estimated that rebuilding Libya's infrastructure will take at least a decade [27].

2.3. System requirements

For a country to adopt renewable energy to generate electricity at a national level, it is vital to have transmission and distribution systems that are capable of supporting the intermittent nature of renewable energy. This section assesses the North African countries grid capacity and robustness. It also looks at the regional interconnections under construction to support export electricity to the neighboring European countries as per the regional plans of DESERTEC, MSP and the TRANSGREEN/Medgrid initiatives.

2.3.1. Grid capacity and robustness

Apart from the necessary capacity to carry the extra energy produced, the national grid should be able to support imbalances between demand and generation. Moreover, adequate distribution systems must be in place to absorb excess electricity generation from renewable energy and deliver it to high voltage transmission systems. The quality of the grid system is assessed qualitatively as Poor, Fair and Good in the literature, which could be quantified as 1, 2 and 3 out of 3 respectively. It is then given a score from 1 to 7 by normalizing the 1–3 scale into 2.33, 4.66 and 7 out of 7. A poor grid with plans of improvement in the near future score is3.5 and a fairly robust grid with extra capacity and interconnections score is 5.83, while the maximum score of 7 is assigned to smart grids. The smart grid is equipped with extra capacity to absorb a large amount of additional electricity generated from renewable energy of intermittent nature.

Currently, all the countries have fair national connections except for Tunisia, who has launched the Electricity Distribution Network Rehabilitation and Restructuring Project [18]. With the long-term objective to supply electricity to the European Union, the Maghreb countries are electrically interconnected with each other and synchronized with the European electricity network via an undersea interlink between Morocco and Spain. Further projects for trans-Mediterranean interconnections and the continuing construction of new interconnectors between the Maghreb countries are an indication of a good robust connection that will serve to transport electricity generated from renewable energy [28]. This is why each of the countries' score is 5.83 except of Tunisia that earned a score of 3.5.

2.4. Market infrastructure

Renewable energy technology is a modern technology that still needs investments in research and development (R&D) to demonstrate technical viability. A successful market entry strategy requires additional investment to further improve performance, and to develop products for specific markets. Apart from the technical barriers that still need to be overcome, renewable energy market entry depends on other relevant factors such as energy sector reforms, maturity of the RETs supply chain, market distortions caused by subsidizing fossil fuels and the general country's goods market efficiency. The below sections discuss these factors for the selected North African countries.

2.4.1. Goods market efficiency

To understand how challenging it is for independent power producers (IPPs) to enter the energy sector, it is important to look at its structure. In countries where the government has monopoly over power generation, transmission and distribution, it is an indication of restriction to private sector entry. Control on transmission and distribution and strict rules and regulations could constrain market forces and reduce market efficiency. Assessing this factor can be done by looking at the competition in the country. Domestic competition can be determined by looking at the intensity of local competition, extent of market dominance, effectiveness of anti-monopoly policy, extent and effect of taxation, and number of procedures to start a business. On the other hand, looking at foreign competition requires assessing the prevalence of trade barriers, trade tariffs, and prevalence of foreign ownership, business impact of rules on foreign domestic investments, burden of customer's procedures and imports as a percentage of gross domestic products (GDP). This study looks at market general efficiency before getting into the particular energy sector regulations in the next section. The scores given by the GCR 2011-12: Tunisia leads with a score of 4.4 followed by Morocco with 4.2, Egypt with 3.7, Algeria with 3.4 [4] and finally Libya with 3.2 [25], due to the strict legal requirements for penetrating the Libyan market [27].

2.4.2. Market deregulations

As part of the whole market efficiency, this section looks at the electricity sector in particular, where an industrial reform is helpful for renewable energy development, It creates a clear legal framework for IPPs under which a power purchase agreements are signed with the transmission company. The evaluation methodology is performed and given in Table 5.

In Algeria, the re-structuring electricity law was enacted in 2002, whereby the monopoly The Algerian Electricity and Gas Corporation (SONELGAZ) was required to unbundle its activities and an independent regulatory body was established. In Tunisia, until 1996, the monopoly on electricity generation and marketing was held by the National Electricity and Gas Corporation (STEG). Since then, liberalization of the energy market has taken place, and the market was opened for IPPs. For Morocco, an initiative was taken in 2007 to liberalize the energy sector and in particular the electricity market. In this context, it has been unbundled into independent enterprises responsible for the generation, transmission and distribution of electricity. The liberalization and opening to national and foreign private investments has introduced competition among the players, increasing market efficiency sector in these three countries: they individually received a score of 5.83 in this regard.

Table 5
Market deregulation scoring method.

Vertically and horizontally integrated market with full state ownership	Vertical integration with some degree of corporatization/ commercialization or contract management	Amendment of electricity law with establishment of Regulatory body	Generation open to private sector but transmission and distribution state owned	Complete private ownership
2.33	3.5	4.66	5.83	7

Egypt's power sector is dominated by the Egyptian Electricity Holding Company (EEHC), a state-owned organization that was established in 2000 as part of plans to liberalize the electricity sector. A number of new gas IPPs were built under Build, Own, Operate and Transfer but their ownership will be transferred to the state after 20 years, giving Egypt a score of 3.5. As for Libya, the electricity market is entirely under the state-owned, vertically-integrated national utility, the General Electricity Company of Libya (GECOL), responsible for power generation, transmission and distribution in Libya. The GECOL owns 100% of the long-range transmission grid and 90% of the distribution grid. A draft law was prepared for the legal unbundling of GECOL into companies for generation and transmission, along with several distribution companies in an attempt to liberalize the sector, but it was never submitted to the legislature [18], giving Libya a score of 2.33.

2.4.3. Supply chain, availability of RETs O and M facilities and quality control

When a domestic supply chains exist, it reduces the burden of importing technology. A well-developed supply channel could minimize logistic issues and increase product visibility and availability. It also reduces technology costs. Additionally, the availability of operations and maintenance (O and M) facilities also ensures the continuous functioning and reliability of renewable energy systems, boosts customer confidence and attractiveness of the technology and increases investors' interest. This is also enhanced by the presence of local standards, codes and certifications needed for large scale projects to ensure good quality maintenance, product acceptability, and reduce risk perception. Good quality control, adequate standards, and moral work ethics improve product reliability and increase its market size. Assessment of this factor is made according to the method of poor, fair, good and very good and distribution of scores this sub-factor is given in Table 6.

Egypt leads in this regard due to its initiatives to develop the wind industry supply chain. The New and Renewable Energy Authority (NREA) is promoting the localization of wind technology equipment manufacturing based on technology transfer or joint venture. The NREA has invited several wind manufacturers to discuss this trend with the Egyptian concerned entities. In terms of maintenance, repairs and rewinding of generators have been done locally since 2005 [29]. Based on this Egypt receives a score of 5.83. In Algeria, the Ministry of Energy and Mining supports the development of solar plants: an established silicon production industry is able to supply the local, MENA and European markets for solar equipment [13]. Algeria receives a score of 4.66. Morocco has a number of small-and medium-size enterprises populating the solar and wind energy sector letting is score of 4.66. The country has the first photovoltaic module factory started manufacturing high efficiency solar cells. The factory will produce both mono- and poly-crystalline photovoltaic modules [30]. In Libya, a plan to promote renewable energy that will stimulate local manufacture of equipment for solar and wind technology [18]. But nothing is in place yet, so Libya earns a score of 2.33. But the region currently lacks CSP equipment manufacturing facilities as well as specialized operation and maintenance services, especially in Libya.

Table 6
Renewable energy supply chain, O and M and quality control scoring method.

No supply Chain or O and M or quality standards	Contractors importing foreign equipment and O and M	Manufacturing part of the RETs supply chain	Developed supply Chain, O and M facilities and quality standards
1	2.33	4.66	7

2.4.4. Market distortions and competitive advantage of RETs

Renewable energy is already competitive for rural electrification and water pumping applications in remote and isolated areas where access to the grid is expensive due to long distances and dispersed households. But they are not yet generally competitive in the broad energy market, partly due to large subsidies in oil producing countries, abundant conventional resources and absence of environmental constraints. Table 7 shows the tariffs of electricity employed in North African countries in 2009 along with their market distortions scores. The assessment is made by comparing the country electricity tariffs to international tariffs employed worldwide today. Less electricity tariff discourages for the development of RETs and gives less RE-Readiness score.

Morocco and Tunisia both have higher rates than their neighboring countries, mainly due to their lack of local fuel resources. This eases competition with renewable energy and incentivizes investments in RETs.

2.5. Energy access

2.5.1. Expected energy demand growth

Economic and population growth as well as increased reliance on desalination water supplies in the region are main drivers for electricity demand growth. Algeria's power demand growth is expected to expand by an average of 5.1% a year from 35 billion kWh in 2010 to about 60 billion kWh in 2020 [31]. Egyptian electricity demand is projected to continue to grow by 6% and 33,900 MW to be added within 2012–2027 based on the latest National Development Plan of 2007 [18]. Morocco's electricity

Table 7
Power tariffs in North Africa [31].

	North Africa comparative tariffs (USc/kWh in 2009)					
	Capacity (KW)	Algeria	Egypt	Libya	Morocco	Tunisia
Social tariff (100 KWh/month)	1	4.84	1.34	1.52	13.44	9.05
Single phase domestic usage (200 KWh/month)	2	5.59	1.56	1.52	13.44	9.96
	4	6.07	1.56	1.52	17.56	10.20
Triphase domestic usage (600 KWh/month)	6	6.09	2.50	1.52	13.44	11.48
	10	6.14	2.50	1.52	16.22	11.64
Commercial usage (1800 KWh/month)	12	6.66	8.02	3.64	11.52	12.44
	15	6.70	8.02	3.64	12.76	12.48
Semi-industrial and motive power (2500 KWh/month)	20	6.68	8.33	3.18	12.62	12.53
	25	6.72	8.33	3.18	13.44	12.58
Score (1–7)		**2.33**	**1**	**1**	**7**	**4.66**

demand is expected to keep growing at a rate of 8% per year until 2015. GECOL in Libya estimates average annual growth of 10–12% in the period between 2009 and 2025. Forecasted peak demand will reach 15,078 MW by 2020 and hit 18,417 MW by 2025 [33]. Power demand growth is more likely to remain in the current trend of 5–6% in Tunisia [34]. Since the selected countries at hand plan to produce electricity to export to Europe, the foreign demand is guaranteed, regardless of domestic growth. Algeria earns a score of 4 in this regard. Egypt, Morocco and Tunisia individually receive a score of 5, and Libya scores 6 towards RE-Readiness.

2.5.2. Electrification rate and quality of electricity supply

Electrification rates are above 95% in the North African region, due to electrification programs and well-connected networks. Algerian electrification exceeds 98% and the rate reached 100% in the year 2005 in Libya. In Tunisia, due to the government's substantial efforts over the past 30 years, electrification rate went up from only 6% of the population connected to the power grid in the 1970s, to about 50% in 1990, to 99.5% in 2008 as estimated by the state-owned utility company. In Egypt, electrification rate was approximately 99.4% in 2008. In Morocco, 91% villages have been connected with grid system and remaining to be connected by decentralized system driven by photovoltaic, wind and hydro [18]. Remote rural areas far from the national grid are financially more viable to produce electricity from RETs.

Scores given by the Global Competitiveness Report give an indication of how well the country performs in this factor. RE-Readiness score depends on the extra capacity requires to be installed and the quality of electrcity supply. Algeria and Egypt receive a score of 2.4 individually, Morocco score is of 2.1 and Tunisia 1.3 based on GCR [4] while Libya earns a score of 2.7 [25].

3. Institutions

3.1. General institutions

General institutions score gives an indication of how committed the government is to establish institutional framework, in terms of property rights, ethics and corruption, undue influence such as judicial influence and favoritism in decisions of government officials, security and government inefficiency. The inefficiency is determined by wastefulness of government spending, burden of government regulation, efficiency of legal framework in settling disputes, efficiency of legal framework in challenging regulations and transparency of government policy making. Those factors are the most significant in determining how fit the public institution is to implement its set renewable energy targets. The government should start wisely allocating the required budget to meet the goals; wasteful spending and corruption. By reducing the burden of government regulations and administrative issues to get permits such as site selection and construction permits and access to the grid, it would encourage developers to invest in renewable energy projects. Efficiency of legal framework in settling disputes and challenging regulations protects investors' rights and reduces perceived risks while transparency in government policy making provides security and stability and renders renewable energy policy reliable, and therefore also reduces the risk of renewable energy projects. The GCR has given the score of general institutions for all countries. Tunisia receive a score of 4.5, Morocco 4.0, Egypt scores 3.8, Algeria scores 3.1 and Libya scores 3.3 [4].

3.2. Key policies

All of the studied countries have ratified the Kyoto Protocol and are looking for opportunities in the framework of the Clean Development Mechanism (CDM) to both ensure financing renewable energy projects and boost foreign investments. Algeria, Egypt, Morocco and Tunisia have already implemented their Designated National Authority while Libya is in the process of doing so. The five countries have identified opportunities for reducing the emissions of greenhouse gases and prepared portfolios of CDM projects based on national priorities and have implemented capacity building programs.

In 2008, the French government led the creation of the Union for the Mediterranean that launched the MSP to tackle issues posed by increasing energy demand, security of supply and environmental sustainability in the Euro-Mediterranean region [28]. The MSP targets the addition of 20 GW of new solar and wind capacity by 2020, along with the necessary electricity transmission requirements, including international interconnection. The deployment is expected to be financed by the World Bank and the European Development Bank. Establishment of the Regional Centre for Renewable Energy and Energy Efficiency (RCREEE), an independent regional think tank based in Cairo in 2008 is dedicated to promotion of renewable energy and energy efficiency, comprising 10 North African countries. The RCREEE encourages the participation of the private sector in order to promote the growth of regional industry of renewable energy and energy efficiency. In 2009, the DII was announced and the Arab Maghreb Union launched the regional power project COMELEC. It aims to increase inter-connection between the Maghreb states, as well as further development of inter-connections with Europe for the purposes of electricity trading.

3.2.1. Institutional framework

Table 8 shows the existing institutions in each of the studied country that are related to energy and power including RETs. Although many institutions exist in the region, there is a lack of coordination and cooperation between these institutions regionally and nationally. Also, there is a lack stable institutional and regulatory framework, but this situation is changing quickly [10].

The interest of European countries in the success of renewable energy deployment in the region also increases chance of success with the implementation of capacity building and knowledge transfer strategies. But policies and deployment strategies must fit well with the country's overall economic, energy and environmental plans. It is clear that RETs deployment is relying on subsidies and incentives offered by the governments. Higher cost of electricity from renewable energy than conventional sources remains the main obstacle for renewable energy development [28]. Countries RE-Readiness scores are assessed based on criteria: existence of clear legislation, timely implementation of legislation, comprehensive guidance on the interpretation of legislative requirements, harmonization between stakeholders, clear communication from National Regulatory Authorities (NRAs), and adequate appeals processes and adequate NRA enforcement powers [37]. Algeria, Egypt, Morocco and Tunisia receive individually a score of 5.83 while Libya scores 4.66 based on their institutional framework.

3.2.2. Identified targets and policy mechanisms

Renewable energy and energy efficiency targets are essential as they guide policy-makers during decision-making by helping them formulate steady policies. Set targets also give investors and entrepreneurs ideas about future investment opportunities for their strategy development and business plans. A set renewable energy target to produce electricity for the selected countries is given in Table 9.

The RE-Readiness assessment of set targets is made following the SMART (Specific, Measurable, Achievable, Reasonable, Time-bound) logic, and a country is given a point for each characteristic

Table 8
Key stakeholders [11,18,32,35,36].

Algeria	• The Ministry of Energy and Mining (MEM) is in charge of formulating the country's renewable energy policy and the design of the regulatory frameworks. It also designs RE promotion tools • The New Energy Algeria (NEAL), established by the Algerian government and Algeria's national energy companies, is the country's renewable energy agency, responsible for encouraging the production, use, and export of renewable energy • The Algerian Electricity and Gas Corporation (SONELGAZ) is responsible for the production, transportation, and distribution of electricity • The Algerian Research, Production, Transportation, Processing and Trade of Hydrocarbons Corporation (SONATRACH), the largest oil supplier in Algeria and Africa, is one of the shareholders of the Algerian Energy Corporation. It co-finances the Hassi R'mel CSP project with Sonelgaz.
Egypt	• The Ministry of Electricity and Energy (MOEE), is responsible for supplying electricity to meet demand. Among its main objectives are maximizing the use of hydropower and the promotion of renewable energy, as well as interconnecting the Egyptian electricity grid with neighboring countries • The Ministry of Petroleum (MOP), in charge of the petroleum sector. • The New and Renewable Energy Authority (NREA) • The Egyptian Electricity Holding Company (EEHC) • The Rural Electrification Authority (REA) • The Hydro Power Plants Authority (HPPA) • The Atomic Energy Authority (AEA)\the Nuclear Power Plants Authority (NPPA), the Nuclear Materials Authority (NMA) • Egypt Wind Energy Association (EGWEA) to promote and support wind energy development in Egypt by facilitating the exchange of technical information, expertise and experience in the wind energy sector
Morocco	• The Ministry of Energy, Mining, Water, and Environment (MEMEE) is the main decision maker in the energy sector. It prepares and defines the RE strategy, including the design of the regulatory framework and the promotion of tools for the development of renewable energy projects • The Center for development of Renewable Energies (CDER) responsible of renewable energy based decentralized rural electrification, independent power production, energy saving, resource assessments and firewood demand management. Its creation in 1982 was a milestone in the integration of renewable energy in national policy. The CDER was transformed to ADEREE in 2010. • Renewable Energy and Energy Efficiency Agency (ADEREE) initially under the CDER, the agency was formed under the law 16.09 of January 13th 2010 and is responsible for implementing the government policy in the fields of renewable energies and energy efficiency • Moroccan Agency for Solar Energy (MASEN) is responsible for the oversight and monitoring of solar electricity generation programs and projects (design, selection of locations, studies, selection of operators, implementation and operational follow ups). • National Electricity Office (ONE) is Morocco's electricity provider. The agency is responsible for the satisfaction of electricity demand at the best possible cost and quality of service.
Libya	• The Renewable Energy Authority of Libya (REAOL), originally a solar research center within GECOL, became a dedicated agency depending on the Ministry of Electricity, to develop concrete projects concerning renewable energy. After the Ministry of Electricity was disbanded in 2008, its responsibilities were shifted to the Energy Council • The Energy Council was formally in 2009; it is chaired by the Prime Minister, and is comprised of the Ministers of Industry and Economic Development, Planning and Finance, and Municipalities together with the Chairmen of the Environmental General Authority, REAOL, GECOL, the NOC, the Atomic Authority, the Solar Energy Research Centre, the Libyan Bank and the National Security Council. The Energy Council is responsible for all activities in the energy sector, including regulatory functions for both the oil and electricity sub-sectors. It serves as a mechanism for decision making in energy related matters. It also performs tasks that would normally be done by a Ministry of Energy, such as structuring of the sector, investment management, and the provision of information. The Council micro-manages the operating entities, creating conflicts of function, risks of confusion and delays. The current institutional setting is not favorable for sustainable long-term policies and strategies • The Centre for Solar Energy Studies (CSES) performs studies and research programs in the field of solar energy, and promotes the use of solar technology in Libya.
Tunisia	• The Ministry of Industry, Energy and Small and Medium Enterprises is responsible for the formulation of the country's energy policy. It prepares and defines the RE strategy and the regulatory framework for RE provision; and the Ministry of Agriculture, Environment and Water Resources is responsible f or the exploitation of hydropower. • The Interdepartmental Commission of the Independent Electricity Production (CIPIÉ), oversees the proposals submitted by bidders for IPPs, and offers input such as conclusions and recommendations to the Higher Commission of the Production Independent of Electricity (CSPIE), who is an interdepartmental commission in charge of selection of the winning bid for each IPP project. • The National Electricity and Gas Corporation (STEG) is in charge of generation, transmission, and distribution of electricity. STEG is also the sole buyer of electricity produced by the private sector and it promotes hydro and wind energy projects and is developing programs for CSP and PV projects • The National Agency for Energy Conservation (ANME) established to implement the government's energy policy. • STEG-Renewable Energy (STEG-ER) provides technical expertise in RE technologies • Tunis International Centre for Environmental Technologies was founded in 1996 to promote environmental technologies. It is accountable to the Tunisian Ministry of the Environment.

Table 9
Renewable energy set targets [18,38–40].

Algeria	Short-term goal of 5% renewable energy electricity target by 2017 and a 20% overall renewable energy coverage on the long run by 2030, of which 70% is generated by CSP, 20% by wind and 10% by PV
Egypt	20% of energy from renewable sources by 2020. It aims to realize a 7200 MW wind power capacity.
Libya	Intermediate targets of 6% renewable energy by 2015 and 10% by 2020 and a long term goal of reaching 25% of energy supply by 2025, rising to 30% by 2030.
Morocco	20% of electricity generation from renewable sources by 2012, 42% of the total installed capacity from renewable energy by 2020: 2000 MW from wind, 2000 MW from solar and 2000 MW from hydro and provide more than 20% of the country's total electricity consumption by 2020.
Tunisia	Tunisia has set more modest renewable electricity goals: until 2016, projects in CSP and PV plants will only add up to a total capacity of 120 MW. In terms of wind capacity, around 330 MW of installed capacity are foreseen by 2016, while 1200 MW shall be reached in 2020 and 1800 MW by 2030.

that is satisfied in its set goals. The studied countries have introduced policy mechanisms to promote diffusion of RETs shown in Table 10.

The policy framework of a country is assessed based on the implementation of mechanisms belonging to each of the categories identified by REN21 [42]. The formation of a regulatory body in

Table 10
Implemented policies and measures based on IEA/IRENA Global renewable energy policies and measures database [41].

Country	Year	Name of Policy	Type	Target	Sector	Status
Algeria	1999	Law 99-09 on the Management of Energy	Policy processes	Multiple RES	Framework Policy	In force
	2002	Law 02-01 on Electricity and Gas Distribution	Regulatory instruments	Multiple RES	Electricity	In force
	2004	Law 04-90 on Renewable Energy Promotion in the Framework of Sustainable Development	– Policy Processes – RD and D – Regulatory Instruments	Multiple RES	Electricity	In force
Egypt	2007	New National Renewable Energy Strategy	– Incentives/Subsidies – Policy Processes – Regulatory Instruments	– Multiple RES – Wind	Electricity	In force
Libya	2007	Law 426 to create the Renewable Energy Authority of Libya (REAOL)	– Policy Processes – Regulatory Instruments	– Solar PV – Solar Thermal – Wind	Multi-sectoral Policy	In force
Morocco	2009	Renewable Energy Development Law 13.09	– Policy Processes – Regulatory Instruments	– Solar PV – Solar Thermal – Wind	Electricity	In force
	2010	National Integrated Project for Solar Electricity Production and National Agency for Solar Energy	– Policy Processes – Public Investment – RD and D	Solar	Electricity	In force
	2010	National Agency for the Development of Renewable Energy and Energy Efficiency	Policy processes	Multiple RES	Multi-sectoral Policy	In force
Tunisia	2004	Law 2004-72 on Energy Efficiency: Renewable Energy Provisions	– Policy Processe – RD and D – Regulatory Instruments	Multiple RES	Framework Policy	Superseded
	2005	PROSOL Residential: Incentives for solar water heaters	Incentives/Subsidies	Solar Thermal	Heating and Cooling	In force
	2005	Law and Decree on Energy Conservation and Renewable Energy	Policy Processes	Multiple RES	Framework Policy	In force
	2006	Law 2005-82 on Energy Efficiency Fund (FNME)	– Incentives/Subsidies – Policy Processes – Public Investment	Multiple RES	Multi-sector Policy	In force
	2007	PROSOL Tertiary: Incentives for commercial solar water heaters	– Education and Outreach – Incentives/Subsidies	Solar thermal	Heating and cooling	In force
	2008	National Energy Efficiency and Renewable Energy Program 2008-2011	– Incentives/Subsidies – Policy Processes – RD & D	– Bioenergy – Solar PV – Wind	Multi-sectoral Policy	In force
	2008	National Energy Efficiency Program 2008-2011: Renewable Energy Provisions	– Education and Outreach – Financial – Incentives/Subsidies – Policy Processes – RD & D	– Bioenergy – Solar PV – Wind	Framework Policy	In force
	2009	Tunisian Solar Plan (PST) 2010-2016	– Policy Processes – Public Investment – Voluntary Agreement	– Solar PV – Solar Thermal – Wind	Electricity	In force
	2009	Law 2009-7 on Energy Efficiency: Renewable Energy Provisions	– Incentives/Subsidies – Policy Processes – Regulatory Instruments	Multiple RES	Electricity	In force
	2009	Decree 2009/362 on Renewable Energy and Energy Efficiency Premiums	Incentives/subsidies	– Multiple RES – Solar Thermal	Multi-sectoral Policy	In force

charge of renewable energy, the establishment of a renewable energy law that binds utilities to buy electricity generated from IPPs following clearly set PPAs, the availability of financial incentives and tax cuts, and the provision of public finance. Assessed RE-Readiness scores are 6.0 for Algeria and Egypt, 3.3 for Libya. 6.4 for Morocco and 6.8 for Tunisia.

3.3. Financial market development

To overcome one of the most pressing barriers to the diffusion of RETs, especially in low-income countries, it is important to assess the well-being of the financial market. It determines investors' capability to develop renewable energy projects. This readiness factor looks at the efficiency of the financial market, in terms of availability and affordability of financial services, possibility of financing through equity market, ease of access to loans, venture capital availability, and restriction on capital flows. It also looks at the trustworthiness and confidence in the financial market, in terms of soundness of banks, regulation of security exchanges and legal rights index. The GCR scores are: Morocoo ranks the highest with a score of 4.2, followed by Tunisia scoring 4.0, Egypt 3.8, Lybia 3.0 and finally Algeria 2.6 [4,25].

3.4. Macroeconomic environment

The stability of national macroeconomic environment is vital to determine its ability to invest in renewable energy development. The government's capability to invest in energy sector weakens when it has to make high-interest payments on its past debts. Also, developers do not operate efficiently when inflation rates are high, and investors are not encouraged when cost of capital is elevated. This macroeconomic factor is determined by the government budget balance, national savings rate, inflation, interest rate spread, government debt, and country credit rating. A healthy macroeconomic environment signals government ability to subsidize renewable energy and the private sector's ability to invest in new projects. The Global Competitiveness Report scores of this factor show that the healthiest macroeconomic environment is that of Libya and Algeria with a score of 5.7 idividully, followed by Morocco 5.6, Tunisia 5.3, and finally Egypt with a score of 3.7 [4,25].

4. Human capital

The human capacity of a country determines the level of awareness of its consumers and decision makers, in terms of advantages and inconveniences for development a new technology. Moreover, it measures their ability to select and sustainably operate the most appropriate technology, as well as managing and maintaining new projects.

4.1. Technical and commercial skills

4.1.1. Higher education and training

This sub-factor of RE-Readiness is an indicator country's technical capacity in terms of skilled and trained personnel to plan, develop, operate and maintain RETs projects. It assesses the quantity and quality of education, such as secondary and tertiary education enrollment rates, the quality of the educational system, math and science education, management schools and internet access in schools. These give an understanding of how well equipped human capital is to implement a new technology. This indicator incorporates the quality of on-the-job training, such as local availability of specialized research and training services and extent of staff training, to determine how achievable switching to renewable energy projects for power generation. Tunisia leads with a RE-Readiness score of 4.7, followed by Libya and Morocco 3.6, Algeria scores 3.5 and Egypt scores 3.4 [4,25].

4.1.2. Capacity building

In general there is a lack of awareness and information about renewable energy technologies among policy makers, energy planners, and potential users of the technology. But considerable capacity building and training efforts have been made in Morocco, Algeria, Tunisia and Egypt scoring 4.66 while Libya scores 2.33. But there is still need for capacity building programs in development of RETs in the region for various stakeholders: decision makers, consultants, engineers, etc. [28].

4.1.3. Available renewable energy experts

There are very few specialized consultancy firms that provide consultancy services in the area of renewable energy in the North African region. Renewable energy education has been introduced in graduate studies programs, such as the Master of Science in Sustainable Energy Management program in Al Akhawayn University in Morocco [43], and the Egypt–Germany Masters Program in the field of Renewable in Cairo University and the University of Kassel [44]. Renewable energy experts related to RE-readiness score is 4.66 each for Morocco, Algeria, Tunisia and Egypt while Libya scores 2.33.

4.1.4. Labor market efficiency

In addition to the availability of renewable energy experts, it is vital to assess the country's ability to retain talent. The labor market efficiency indicator measures the efficacy of the labor market. It gives an idea of the country's efficient use of talent, in terms of pay and productivity, reliance on professional management, brain drain and female participation in the labor force. The Global Competitiveness Report gives the scores on labor market efficiency are: Algeria 3.4, Egypt 3.2, Libya 2.8, Morocco 3.5 and Tunisia 4 [4,25].

4.2. Technology adaptiveness and diffusion

It is important to assess country's succeeds in keeping up latest technologies such as RETs adoption. This is measured by its people's ability to adapt with technology changes and the level of innovation and research and development (R&D).

4.2.1. Technological adoption readiness

This factor measures adoption of existing technologies and capacity to leverage ICT in daily activities and processes to increase efficiency and competitiveness. To assess this sub-factor readiness it requires evaluating: existing technologies, firm-level technology adoption and foreign domestic investments, technology transfer, number of internet users, internet bandwidth to evaluate the ICT use. We get an indication to adopt RETs. The Global Competitiveness Report scores are: Algeria 2.8, Egypt 3.3, Libya 2.9, Morocco 3.7 and Tunisia 3.8 [4,25].

4.2.2. Innovation and R&D

Aside from technological readiness, this factor measures the nation's capacity for innovation, quality of scientific institutions, investment on R&D, university-industry collaboration in R&D. It assesses government procurement of advanced technology products, availability of scientists and engineers, utility patents, and intellectual property protection. It gives an indication of human capacity related to use latest technologies. It signals import and customize technologies to fit the local requirements and specifications. The scores assigned by the Global Competitiveness

Report 2010 are: Algeria 2.4, Egypt 2.8, Libya 2.4, Morocco 3 and Tunisia 3.6 [4,25].

4.3. Awareness among consumers, investors and decision makers

4.3.1. Resources availability

All of the countries have made considerable resource assessment efforts and most of them have made findings of renewable energy potential available to public. In Egypt, a Wind Atlas for Egypt was published recently by the New and Renewable Energy Authority (NREA) and the Egyptian Meteorological Authority (EMA), in cooperation with Riso National Laboratory [45]. In Libya, the production of a detailed solar atlas is one of the objectives of the GECOL in relation with its renewable energy policy [17]. A first Wind Atlas for the Coastal Regions of Libya was developed by Yousef M.A. Kalifa (CSES) in 1998 [10]. Algeria, Moroco and Tunisia have updated and comprehensive portals that show all countries resource potential is high and receive higher RE-Readiness scores.

But in general, there is still lack of awareness and information of RETs among policy makers, energy planners, and potential users of these technologies. For example in Tunisia, the National Agency for Energy Conservation (ANME) has made considerable efforts in this regard, but these remain modest in comparison to the efforts made for energy efficiency [28].

4.3.2. Consumer and social acceptance

Poor maintenance of installed solar water heating systems and photovoltaic (PV) modules in rural areas and poor quality equipment led to malfunctioning systems that contribute deteriorating reputation of the technology itself [10]. As a result, consumer reliance on RETs decrease and the scores towards RE-Readiness are relatively less in all the selected countries.

5. Assessment of RE-readiness for the selected countries

After getting all quantitative values for all factors and subfactors, we weighted them based on the method discussed in the methodology section. Total weight of 100% is divided by subfactors given in Table 11. The Table 11 sumarizes all surveyed and assessed RE-Readiness scores for the selected countries. Morocco got the highest RE-Readiness score is 5.27 out of 7. It means Morocco is more ready to integrate the RETs than other other selected countries (Table 11). Libya is not ready for the deployment of RETs and score is 3.80 due to lack of its insfrastructure.

Table 11
Summary of the RE-Readiness scores for the selected North African countries.

Factors along the pillars	Weight 100%	Algeria	Egypt	Libya	Morocco	Tunisia	Source
		Score (1–7)					
Infrastructure							
Assessment of natural Resources		**5.125**	**5.625**	**4.875**	**6.875**	**5.5**	
Renewable energy potential	6.20	6.50	7.00	6.00	7.00	6.00	Section 2.1.1
Energy security	3.00	1.00	1.50	1.50	6.50	4.00	Section 2.12
Country overall infrastructure	**0.70**	**3.70**	**3.90**	**3.20**	**4.30**	**5.00**	[4,5]
System requirements		3.70	3.90	3.20	4.30	5.00	
Grid capacity and robustness	3.90	**5.83**	**5.83**	**5.83**	**5.83**	**3.50**	Section 2.31
Market infrastructure		5.83	5.83	5.83	5.83	3.50	
Goods market efficiency	2.40	**4.56**	**3.74**	**2.21**	**5.55**	**5.14**	[4,5]
Market deregulations	6.60	3.40	3.70	3.20	4.20	4.40	Section 2.4.2
Renewable energy supply chain development & availability of RETs O&M facilities	4.60	5.83	3.50	2.30	5.83	5.83	Section 2.4.3
Market distortions	3.10	4.66	5.83	2.33	4.66	4.66	Section 2.4.4
Energy access		2.33	1.00	1.00	7.00	4.66	
Expected energy demand growth	2.90	**3.50**	**4.19**	**4.98**	**4.10**	**3.85**	Section 2.5.1
Electrification rate and quality of electricity supply	0.90	4.00	5.00	6.00	5.00	5.00	[4,5]
Institutions							
General institutions	**2.10**	**3.10**	**3.80**	**3.30**	**4.00**	**4.50**	[4,5]
Key policies		**5.94**	**5.94**	**3.80**	**6.19**	**6.44**	
Identified targets and policy mechanisms	11.90	6.00	6.00	3.30	6.40	6.80	Section 3.2.2
Institutional framework	6.20	5.83	5.83	4.66	5.83	5.83	Section 3.2.1
Financial market development	**4.10**	**2.60**	**3.80**	**3.00**	**4.20**	**4.00**	[4,5]
Macroeconomic environment	**1.40**	**5.70**	**3.70**	**5.70**	**5.60**	**5.30**	[4,5]
Human capital							
Technical and commercial skills		**4.42**	**2.52**	**4.37**	**4.44**	**4.60**	
Higher education and training	2.40	3.50	3.40	3.60	3.60	4.70	[4,5]
Capacity building	9.00	4.66	2.33	4.66	4.66	4.66	Section 4.1.2
Renewable energy experts	8.10	4.66	2.33	4.66	4.66	4.66	Section 4.1.3
Labor market efficiency	2.40	3.40	3.20	2.80	3.50	4.00	[4,5]
Technology adaptiveness and diffusion		**2.54**	**2.98**	**2.58**	**3.25**	**3.67**	
Technological adoption readiness	2.40	2.80	3.30	2.90	3.70	3.80	[4,5]
Innovation and R&D	4.30	2.40	2.80	2.40	3.00	3.60	[4,5]
Awareness among consumers, investors and decision makers		**6.01**	**6.01**	**4.16**	**6.01**	**6.01**	
Resource availability	9.00	7.00	7.00	4.66	7.00	7.00	Section 4.3.1
Consumer awareness and social acceptance	2.40	2.30	2.30	2.30	2.30	2.30	Section 4.3.2
RE-Readiness Index		**4.7644**	**4.3080**	**3.8030**	**5.2738**	**5.1132**	

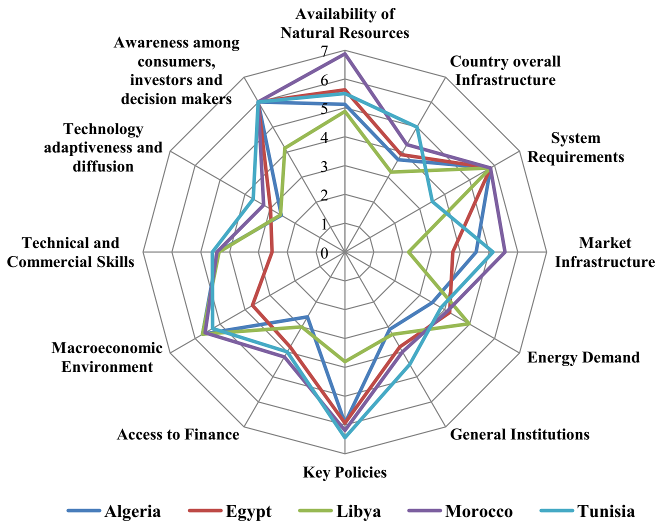

Fig. 3. RE-Readiness factors in the selected countries for the deployment of RETs.

Based on the assessed and surveyed scores of RE-Readiness of the selected counties, Fig. 3 demonstrates the results of their readiness for deployment of RETs. It is evident that the North African countries share many attributes to enhance their RE-Readiness, mainly due to some initiatives made on the regional level after the expression of interest of European countries in the investment in renewable energy in their neighboring countries. For example, the development of new robust grid interconnections that would transport the electricity generated from RETs to Europe, or the expected future energy demand growth, which guarantees that there will be a market for the electricity produced.

Fig. 3 shows the common weaknesses are financial market development and technology adaptiveness and diffusion. It is clear that Libya is lagging behind in many aspects, mainly due to the weakness of general competitiveness characteristics, such as general infrastructure, human capital development, financial market development, and general institutions and market infrastructure. The past difficulties in penetrating the Libyan market, coupled with the unreliability of its institutional framework have decreased the attractiveness of investing in major renewable energy projects. It would be competing with among the lowest prices of energy globally. Egypt has the lowest prices for energy in the region. Although the country is heavily endowed with renewable energy resources, it richness in hydrocarbon resources and large hydroelectric projects has made difficulties for other RETs projects. Despite Egypt has abundant oil and gas resource, the county's macroeconomic development is lagging, limiting the government's spending capability on renewable energy projects.

Algeria is very rich in hydrocarbon resources, but it is planning on leveraging its renewable energy sources to increase its exports energy to Europe. Its weak financial market development will however make borrowing capital to invest in big projects. However, Algeria has established a robust institutional framework to support RETs diffusion process. Morocco has also a robust institutional framework. But dependency on foreign oil, coupled with its diversified potential of renewable energy resources, boosts its RE-Readiness. The country leads among its peers in terms of natural resources availability.

Tunisia leads on several aspects relating to its competitiveness, such as its overall infrastructure, general institutions, financial market, technology adaptiveness and technical and commercial skills. It has developed institutional framework to support its modest renewable energy development goals. However, its renewable energy potential is limited to solar, which will delay the diffusion process until the solar technology picks up and becomes more competitive with fossil fuels.

5.1. Identified gaps and strength of RETs development

The findings on RE-Readiness to be summarized using a SWOT (strengths, weaknesses, opportunities and threats) analysis. The SWOT analysis is intended to maximize strengths and opportunities, minimize external threats, and transform weaknesses into strengths. It is designed to be used in the preliminary stages of decision-making and as a precursor to strategic management planning. The analysis results are presented below.

Strengths and opportunities to develop RETs in the selected studies countries:

- Substantial and diversified renewable energy resources;
- Export electricity to Europe;
- Morocco, Tunisia and Algeria have sound policy framework;
- Good awareness among investors and decision makers about the potential of renewable energy.

Weaknesses and threats:

- Morocco and Tunisia lack on human capital and required more capacity building and technological adoption readiness;
- Tunisia has poor grid infrastructure;
- Algeria, Egypt and Libya: competitive disadvantage of renewable energy, poor institutions, and underdeveloped financial market;
- Egypt has poor macroeconomic environment and overall infrastructure;
- Egypt and Libya need market deregulation to encourage private companies;
- Libya lacks a regulatory framework.

6. Conclusions

The North African countries are endowed with abundant renewable energy resources. Although some of them are among the largest oil exporters in the world, they have set firm renewable energy development targets for the near future. If they manage to meet their targets, they will benefit their economies by exporting fuels at high returns, creating jobs, and avoiding external costs of burning fossil fuels. However, among the biggest challenges they have been facing in their institutional structure. The political changes that have been witnessed over the last years will improve the legal and institutional framework in favor of RETs penetration. Energy demand in this region is growing very high that relates to economic growth. The increasing demand of clean energy in particular, as the world asserts its commitment to sustainable development, especially in Europe. The growing European demand for clean electricity has provided the North African countries with the opportunity for foreign investments in RETs, capacity building and knowledge transfer. This way, North African countries have a chance to collaborate with their neighboring countries to minimize the RE-Readiness gaps for development of RETs. North African countries own strengths towards integration of RETs and European experience in clean technologies can be used to meet electricity demand of European countries.

The identified RE-Readiness gaps need to be minimized to develop a sustainable energy system in the North African region. While this region might face certain challenges, such as minimizing energy subsidies and promoting RETs investment, sustained

and strong support by the national government will help to overcome these barriers.

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